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- (54) Liquid crystal display device  
 (57) Between polarizers (1,2) an electro-optic display cell (3, 4, 5, 6) comprises a positive dielectric anisotropy nematic liquid crystal layer 6 having display zones (11) which in the unexcited state differ from, and thus contrast with, other areas in having 90° optical rotatory power. A field E between associated electrodes 7,8 produces homotropic alignment in zones 11 and destroys the contrast, but some zones 11 may have no electrodes for a

permanent display. At zones 11 both cell plates 3, 4 have parallel homogeneous alignment layers (by rubbing or vapour deposition) with mutually orthogonal alignment directions. In the other areas, such directions would be mutually parallel, as shown, or one or both homogeneous alignment layers may be overlaid by homotropic alignment layers (e.g. cathodic sputtering, vapour deposition, or a surfactant). The liquid crystal may contain an optically active additive.

ERRATA

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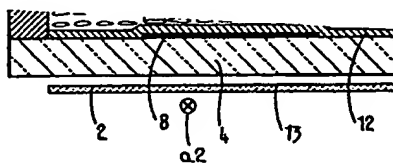
Front page, heading (71) Applicant for l'Hôpital read l'Hôpital

Front page, heading (72) Inventors for Claud read Claude

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FIG. 3



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**(54) Liquid crystal display device**

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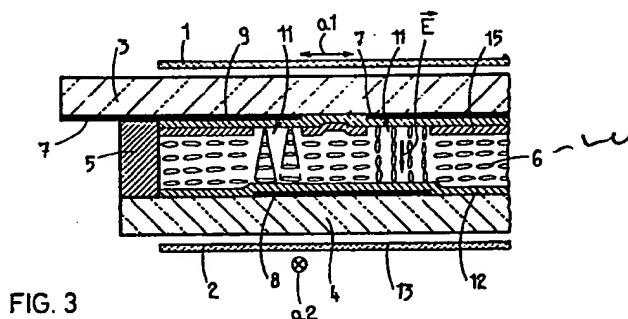


FIG. 3

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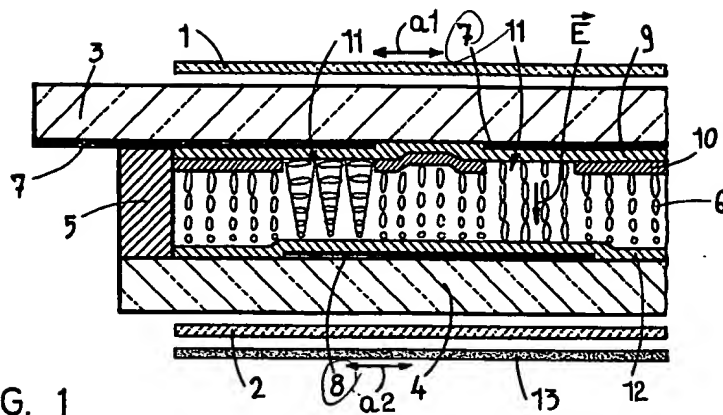


FIG. 1

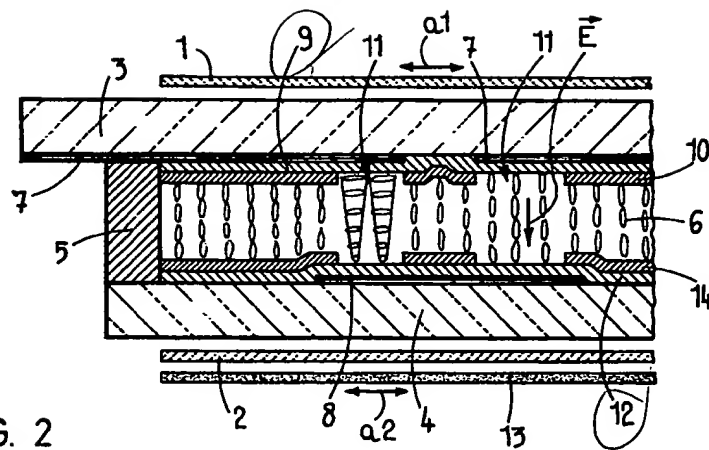


FIG. 2

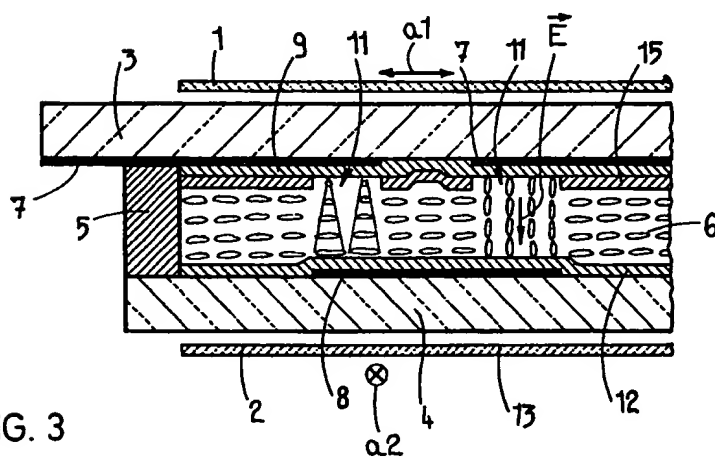


FIG. 3

## SPECIFICATION

## Passiv electro-optic display device

5 The present invention relates to a passive electro-optic display device comprising two polarizers between which is arranged a display cell comprising two transparent plates between which is imprisoned a liquid crystal having a positive dielectric anisotropy and a nematic order, at least locally, the inner faces of the said plates carrying control electrodes and alignment layers of the molecules of the said liquid crystal.

It is to be noted that one knows display cells, called  
15 twisted nematic, disclosed for instance in the U.S. Patent No. 3.918.796, the principle of operation of which is the following: one takes into account the fact that a layer of nematic liquid crystal the molecules of which are orientated along an axis on one of the plates and along an axis which is  
20 perpendicular to the first one on the other plate rotates the plane of polarization of the light through 90°. If crossed polarizers are placed before and behind the cell, only one of the components of the  
25 light is absorbed and the cell is transparent. When a tension is applied to the electrodes of the cell, a field is produced which induces a homeotropic structure of the molecules of the liquid crystal. Hence, the plane of polarization does not rotate in the zones  
30 where the said field exists, so that the second component of the light is thus absorbed and the said zones are then absorbent. While placing the polarizers so as to be parallel to each other, one obtains a cell having a display which is complementary to that  
35 disclosed hereabove, that is to say which is absorbent in the non-activated zones and transparent in the activated zones.

The purpose of the invention is to realize a display device having characteristics which are equivalent to  
40 those previously disclosed but permitting, moreover, to simplify the determination of the topology of the electrodes of the cell, to reduce the consumption of energy and to realize zones in which permanent information is displayed, in the same plane as the  
45 display segments, without any supplementary operation and without increasing the consumption of the cell.

This purpose is reached owing to the means as claimed.

50 The drawing shows, by way of example, three embodiments of the invention.

Figures 1 to 3 are partial sectional views of three embodiments of passive electro-optic display devices.

55 It is to be noted that, in all these figures, the thicknesses of the represented elements have been exaggerated so as to increase the understanding of the drawing.

The passive electro-optic display device represented in Figure 1 comprises two polarizers 1 and 2, the axes of passage a1 and a2 of which are parallel, between which is arranged a display cell comprising two transparent plates 3 and 4, for instance made of glass, maintained at a distance from each other by a  
65 frame 5 to which the said plates are tightly assembled,

thus providing a room in which a nematic liquid crystal 6 is imprisoned, having a positive dielectric anisotropy.

The front plate 3 carries, on its inner face, transparent control electrodes 7, made of SnO<sub>2</sub> for instance, while the rear plate 4 carries, on its inner face, a control electrode 8, also made of SnO<sub>2</sub>. The plate 3 is  
70 innerly coated with a homogeneous planar alignment layer 9, which is itself coated with a homeotropic alignment layer 10. This layer 10 is interrupted opposite the display zones, at places designated by  
75 11 in the drawing, which constitute segments. The plate 4 is entirely innerly coated with a homogeneous planar alignment layer 12 the alignment direction of which is perpendicular to the alignment direction of the layer 9. A diffuser 13 is located behind the rear polarizer 2.

In the area of the cell situated outside the display zones 11, the molecules of the liquid crystal are in contact on the one hand with the homeotropic alignment layer 10 of the plate 3 and on the other hand with the homogeneous planar alignment layer 12 of the plate 4. As is shown by the drawing, the layer 10 produces a homeotropic alignment of the  
85 molecules of the liquid crystal while the layer 12 produces a homogeneous planar alignment of the said molecules which are both parallel to the plane of the cell and perpendicular to the plane of the drawing. This arrangement does not rotate the orientation of the plane of polarization of the light that the polarizer 1 allows to pass through. Consequently, and since the polarizer 2 is orientated in a parallel direction to the polarizer 1, only one of the components of the light is absorbed in the said area  
90 which, nevertheless, remains clear.

In the display zones (segments) 11, the molecules of the liquid crystal are in contact with the homogeneous planar alignment layers 9 and 12. Since the alignment directions of these two layers  
105 are substantially perpendicular to each other, they induce into the liquid crystal a helicoidal structure which rotates the plane of polarization of the light coming from the polarizer 1 through an angle of about 90°. The polarizers 1 and 2 being parallel to each other, it results therefrom that the two components of the light are absorbed, so that the non-activated zones 11 are completely absorbent and appear in dark.

In the activated display zones, such as the zone 11 situated at the right side of Figure 1, the electric field E induces into the liquid crystal a homeotropic structure, that is to say a structure perpendicular to the plane of the cell. Consequently, the plane of polarization of the light is no more modified in its  
120 orientation. Therefore, the activated zones 11 become transparent and are then confused with the surrounding area, also transparent.

The embodiment of Figure 2 differs from that of Figure 1 by the fact that, outside the display zones 11, the rear plate 4 is also covered with a homeotropic alignment layer, designated by 14.

It results from the arrangement as disclosed hereabove that, in the area situated outside the display zones, the liquid crystal has a homeotropic structure. Consequently, the plane of polarization of  
130

the light is not modified and the said area is thus transparent, as in the case of Figure 1. As concerns the operation of the display zones 11, it is identical to that of Figure 1.

5 The embodiment of Figure 3 differs from that of Figure 1 by the fact that, on the one hand, the device operates in the transmission mode, the diffuser 13 having been suppressed, and that, on the other hand, the axes of passage  $a_1$  and  $a_2$  of the polarizers 10 1 and 2, respectively, are perpendicular to each other. Moreover, in the area situated outside the display zones, the layer of the liquid crystal has a planar homogeneous structure and, hence, does not modify the plane of polarization of the component of the light which has passed through the polarizer 1. Consequently, this component is absorbed by the polarizer 2. The area situated outside the display zones will thus appear as dark. Opposite the display zones 11, and in the absence of any electric field  $E$ , 20 the alignment layers 9 and 12 induce into the layer of the liquid crystal a helicoidal structure having the property of rotating through about  $90^\circ$  the plane of polarization of the component of the light which has passed through the polarizer 1. Consequently, this component will not be absorbed by the polarizer 2. 25 The area situated opposite the display zones will thus appear as transparent in the absence of the field  $E$ .

Thus, in the two first embodiments, the display 30 appears in dark on a clear area, which is generally appreciated for the displays which work in the reflection mode while, in the third embodiment, which works in transmission mode, the display appears in clear on a dark area. In these three cases, 35 the control is reversed, the application of the electric field having the effect of "cancelling" or "effacing" the display zones which have to be not visible.

A display in dark on a clear ground is obtained with a device the polarizers of which are parallel to 40 each other while, for a display in clear on a dark ground, the polarizers are perpendicular to each other. The device will operate whatever the relative orientation of the polarizers and of the alignment layers may be. However, if the axes of the polarizers 45 are perpendicular to the alignment direction of one or the other of the planar alignment layers, one will prevent the appearing of interference colors.

It is to be noted that the present device eliminates the usual constraints to which is submitted the 50 determination of the topology of the electrodes. As a matter of fact, where the projection of the pattern of an electrode of the front plate on the rear plate crosses the pattern of an electrode of this rear plate, an electric field is created which tends to orientate 55 the molecules of the liquid crystal according to a homeotropic structure, which structure does not modify the plane of polarization of the light. All the structures disclosed for the area situated outside the display zones having such a behavior, the crossing 60 points do not risk, consequently, to be untimely visible. The realization of the pattern of the nets of the electrodes carried by the two plates is thereby greatly facilitated. Thus, one of the plates could be entirely covered with a conductive layer. This improvement can be considered as an important 65

simplification.

The alignment layers used can be realized diversely:

The homeotropic alignment can be obtained by 70 means of alumina, of magnesium fluoride (see German Patent Application No. 23 30 909 of the firm SIEMENS) or still of magnesium oxide, which can be deposited in any known way, for instance by cathodic sputtering, by deposition in vapor phase or by 75 evaporation under vacuum, according to an incidence substantially perpendicular to the substrate. One can also use a surfactant such as, for instance, the lecithin.

As concerns the homogeneous planar alignment, 80 it can be obtained by means of silicium oxide or other, especially according to the techniques exposed by J.L. JANNING in Applied Physics Letters, Vol. 21, 1972, pages 173 and following. The planar alignment layers can also be realized by a mere 85 rubbing of the substrate, the direction of this rubbing defining the alignment direction.

It must be understood that "planar" does not mean that the axes of the molecules are exactly parallel to the plane of the cell; likewise, "homeotropic" does not mean that these axes are exactly 90 perpendicular to this plane. The parallelism and the perpendicularity are only limit cases.

It is to be noted that, for instance, for impelling a sense of rotation to the helix such as represented in 95 the display zones 11 at the left side of the several figures of the drawing, one can add to the nematic liquid crystal an optically active compound having the effect of inducing, in the absence of outer constraints, a helicoidal structure. Such a mixture 100 has a local nematic order (See E.B. Priestley, R C A Review, Vol. 35, March 1974, p. 84 and followings).

At last, it is to be noted that one can provide, in the present device, permanent display zones, that is to say zones of the same construction as the display 105 zones, but without control electrodes, which, consequently, will remain permanently contrasted. Such zones can, for instance, constitute a frame surrounding the whole display zones.

Likewise, the present arrangement can easily be 110 combined with the conventional arrangement in which the segments which have to be displayed must be activated. One could, as a matter of fact, imagine a display cell comprising, in the same space, two display zones, one realized according to 115 the present arrangement and the other one of the twisted nematic type.

## CLAIMS

120 1. Passive electro-optic display device comprising two polarizers between which is arranged a display cell comprising two transparent plates between which is imprisoned a liquid crystal having a positive dielectric anisotropy and a nematic order, at 125 least locally, the inner faces of the said plates carrying control electrodes and alignment layers of the molecules of the said liquid crystal, characterized by the fact that, opposite the display zones, the plates are covered with substantially homogeneous planar alignment layers, such that the alignment 130

direction defined by the alignment layer of the front plate is substantially perpendicular to the alignment direction defined by the alignment layer of the rear plate, thus inducing into the layer of the liquid

5 crystal, in the absence of any electric field, a helicoidal structure, while, in the area situated outside the display zones, the alignment layers of the two plates define alignment directions of the molecules of the liquid crystal such that there exists  
10 a plane, perpendicular to the plane of the cell, in which are inscribed the great axes of the molecules of the liquid crystal in the whole thickness of the layer.

2. Device as claimed in claim 1, characterized by  
15 the fact that the axes of the two polarizers are perpendicular to the alignment direction induced by one of the alignment layers in the display zones.

3. Device as claimed in claim 2, characterized by the fact that the polarizers are parallel to each other,  
20 being both perpendicular to the alignment direction induced by the same alignment layer.

4. Device as claimed in claim 2, characterized by the fact that the polarizers are perpendicular to each other, being respectively perpendicular to the alignment direction induced by the alignment layers of  
25 each of the plates.

5. Device as claimed in claim 1, characterized by the fact that, in the area situated outside the display zones, the alignment layer of one of the plates  
30 induces a substantially homogeneous planar alignment while the alignment layer of the other plate induces a homeotropic alignment.

6. Device as claimed in claim 1, characterized by the fact that, in the area situated outside the display  
35 zones, the alignment layers deposited on the plates induce homogeneous planar alignments, the alignment directions being parallel to each other and to the direction of the alignment layer with which is coated one of the plates in the display zones.

40 7. Device as claimed in claim 1, characterized by the fact that, in the area situated outside the display zones, the alignment layers deposited on the plates induce homeotropic alignments.

8. A passive electro-optic display device constructed and arranged substantially as herein particularly described with reference to and as illustrated  
45 in Figure 1, Figure 2 or Figure 3 of the accompanying drawings.